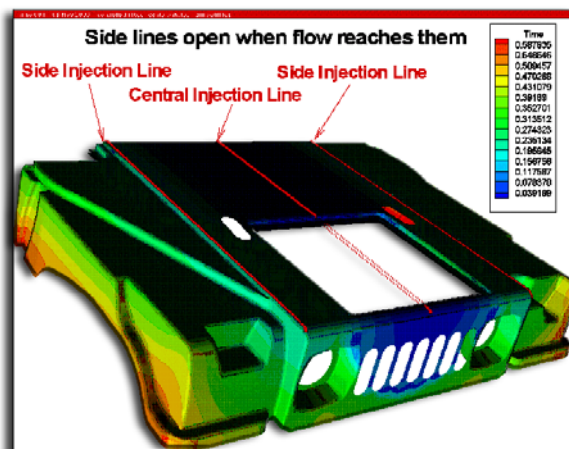# LIQUID INJECTION MOLDING SIMULATION (LIMS)

Liquid Injection Molding Simulation (LIMS) is a software tool that simulates the mold-filling stage of resin transfer molding (RTM) and related processes by modeling flow through porous media by the Finite Element / Control Volume Method. It provides a cost-effective way to verify and optimize mold design by providing a "virtual" mold-filling process to avoid time- and resource-consuming trial and error iterations in physical reality. LIMS has been successfully used to design and simulate an intelligent or adaptive filling process that utilizes sensors mounted on the part and controllable injection hardware, either as a stand-alone program or as a simulation engine for other programs.

LIMS Features

The simulation allows the user to monitor flow progression, pressure distribution, and inflow rates during

Simulation of VARTM injection into a ribbed panel: (a) part as a combined 3D/2D mesh (b) 2D model of distribution media (c) and (d) flowfronts for different permeability values.

*Simulation of controlled sequential injection into a composite vehicle hood.*
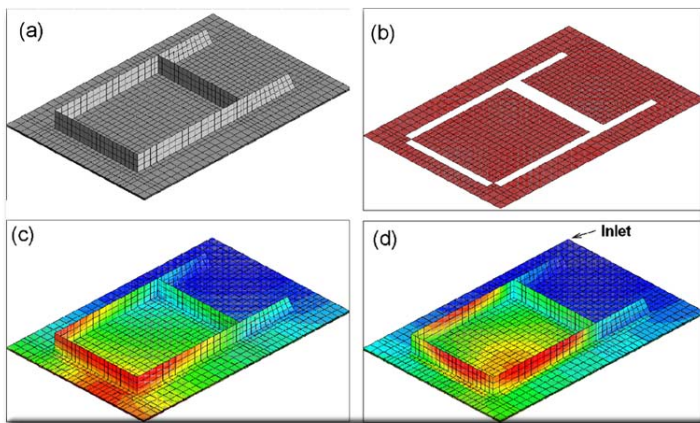
the mold-filling process. Various inlet parameters including location can be changed during the simulated filling. A number of other effects, such as "race-tracking"--the tendency for resin to flow much differently around corners where draped preforms have folded--can be also modeled.

The built-in scripting interpretor allows a user to tailor the simulation for many special issues. Using a simulation script can modify the simulation parameters as needed. It is even possible to modify the material data during the simulation. This allows the user to simulate complex filling schemes such as those using adaptive controls. For example, the evaluation of fiber tow saturation through a set of scripts is available with LIMS distribution.

The program offers three interface options. First, the new graphical user interface allows a user to comfortably modify the material and injection parameters, to run a simulation, and to view the simulation results. This interface allows one to accomplish most common operations - including the creation of the distribution/racetracking channels and distribution media layers - by point-and-click. Second, the command console allows a power user to fully harness the LIMS BASIC interpreter either by directly typing the commands or by using LBASIC scripts. Third, for those interested in utilizing the simulation engine in their own program, say for the purpose of optimization, there is a slave version and dynamically linkable library to be included in the user program.
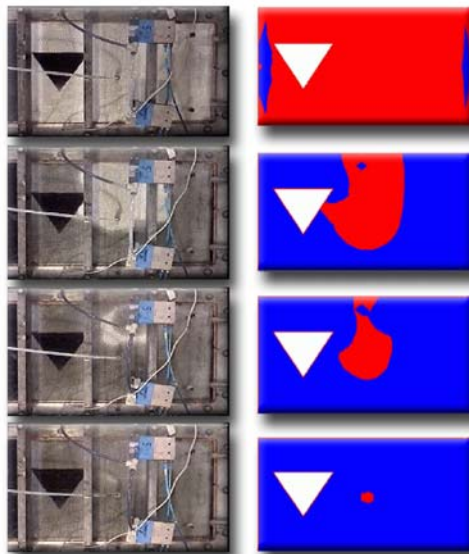
Specific Capabilities

✦ The incremental solution algorithm provides fast simulation of filling. Problems with a few thousand degrees of freedom usually solve within a minute on a typical (1 GHz) workstation.
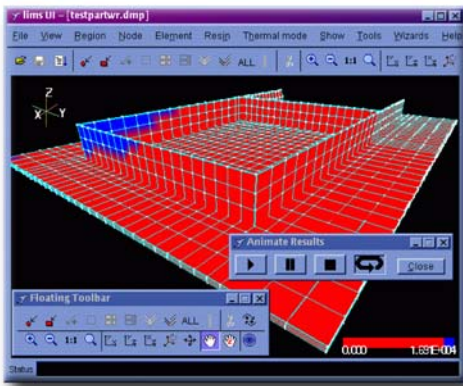
LimsUI: the graphical user interface.

◆ The mold geometry may be a three-dimensional solid, a three-dimensional shell, or any combination of the two. One-dimensional "channel" elements may be added to any geometry to simulate phenomena such as systems of injection tubes or racetracking.

◆ Multiple injection gates, vents, sensors, and inserts are allowed.

◆ The role of preform deformation may be included using additional code, available from the University of Delaware for the simulation of draping (DRAPE) and permeability predictions (PERM). This code is easily integrated with LIMS.

◆ The user may control the simulation through a built-in programming language. The program can monitor the filling and provide on-the-fly control.

◆ All solution data are available to the interpreter during the simulation, thus effectively simulating a large array of sensors. These "numerical" sensors can be used to design or verify mold filling control strategies, as gates and vents can be adjusted in response to signals sent by these sensors.

◆ Dry spots can be predicted.

◆ The heat transfer solution, currently available only for two-dimensional geometries, uses a pseudo three-dimensional temperature field, providing acceptable performance even for non-isothermal simulations.

◆ Output of the results is available at any time during execution of the program. Both an overall snapshot at any given instant and transient tracking of individual values is supported.

◆ On Windows platforms, dynamic link libraries are provided for other programs to run and control LIMS simulation and exchange data with the simulation in an efficient manner. Interfaces to Labview and Matlab have been implemented by the University of Delaware.

◆ A graphical user interface is available. It is tailored to the specific needs of injection molding simulation. It facilitates modifications of preform properties, generation of additional race-tracking and distribution media geometry, execution of filling simulation, and the display of results.

◆ Input files can be prepared in IDEAS, PATRAN, or any program that supports export to an ABACUS input file. Output is available through LIMS' graphical user interface or a TECPLOT package.

System Requirements

Currently, the program is developed mainly for the 32-bit Windows environment: Windows 95, Windows NT 4 and higher. However, ports for UNIX workstations and MS-DOS are available. The system requirements will depend on the type of application. Typically, Pentium processor and 32MB of RAM is sufficient for two-dimensional isothermal self-standing simulations. For non-isothermal simulations or simulations run from within other applications fast Pentium II or better with 128 MB of RAM is recommended. For realistic three-dimensional simulations large amount of RAM - at least 256 MB - is recommended.

Comparison of experimental flow-fronts (left) and simulation predictions (right).

Technical Contact:

Prof. Suresh G. Advani
302-831-8975
fax:302-831-3619
email:advani@me.udel.edu